# THE LOGGERHEAD TURTLE, *CARETTA CARETTA*, IN QUEENSLAND: POPULATION STRUCTURE IN A WARM TEMPERATE FEEDING AREA.

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*Caretta caretta*, resident in the Moreton Banks within eastern Moreton Bay, southeastern Queensland, encompass all size classes from immature turtles with a curved carapace length of 70.1cm to mature adults of both sexes. The population is strongly biased to males (64.8%) and to immature size classes (72.6% of males, 62.1% of females). Sexual maturity does not usually occur at the minimum size for the breeding population but at some larger size. Tag recoveries indicate that most of the adult females resident in this feeding area migrate to breed at the mainland rookeries of the Bundaberg coast. Approximately 11% of the population show signs of anthropogenic impacts and/or health problems which range from fibropapillomas to propeller damage. ☐ *Caretta, Moreton Bay, feeding area, population structure, sex ratio, sexual maturity, migration.*

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The decline in nesting populations of the Loggerhead Turtle, *Caretta caretta* in eastern Australia is the result of mortality of the turtles in their feeding areas (Limpus and Reimer, 1994). While there is considerable knowledge of the breeding biology of *C. caretta* from nesting beach studies, reproduction occupies a small portion of their life history. Most of their life is spent at sea where the biological understanding of them is scant (Dodd, 1988). Concern for the survival of this species in Australia is reflected in *C. caretta* being listed as endangered under the Australian Endangered Species Act, 1992. To improve our understanding of the species in its feeding grounds, the present study was undertaken on a large assemblage of *C. caretta* resident in Moreton Bay.

## METHODS

The present study was done in conjunction with another of *Chelonia mydas* in the same habitats (Limpus et al., 1994). Turtles were captured using the turtle rodeo capture method (Limpus & Reed, 1985) over the intertidal flats and adjacent margins of the Moreton Banks and the Maroom Banks between July 1990 to June 1992. Each turtle was tagged with one or more tags applied in the front flipper axillary tagging positions (Limpus, 1992a). The tags used were either large size, 125 CPT titanium turtle tags (Stockbrands Pty. Ltd., Perth, Western Australia) or inconel 625 turtle tags (National Band and Tag Co. New Port, Kentucky).

Curved carapace measurements were taken using a flexible fibreglass tape measure (±0.1cm) extended over the curve of the carapace. These measurements are the standard measurements used for *C. caretta* in eastern Australia (Bustard, 1972; Limpus, 1985; Limpus et al., 1984). The calibration of fibreglass tape measures was checked regularly against steel rules and a tape measure was rejected for use when length changes exceeded 0.2%. Large barnacles on the carapace likely to interfere with a measurement were removed. Curved carapace length (CCL) was measured along the midline from the junction of the skin and carapace above the neck to the posterior margin of the carapace at the midline junction of the supracaudal scutes. Tails were measured (TLC,± 0.5cm) with either a steel or a fibreglass tape measure from the posterior edge of the midline junction of the supracaudal scutes to the tip of the extended, straightened tail. A negative sign for this measurement indicates a distance short of the carapace margin. Turtles were weighed using 100 or 200kg Salter spring balances (± 0.5, ± 1.0kg respectively). All turtles were measured for CCL except those with damage to the posterior carapace. An unbiased series of turtles were weighed and TLC measured. Each turtle within this two year study was analysed for only one set of measurements, usually those taken at the time of first capture.

TABLE 1. Frequency distribution of 51 recoveries of tagged adult female *Caretta caretta* from Moreton Bay and adjacent waters which were previously tagged while nesting at rookeries in the southern Great Barrier Reef and adjacent mainland (Limpus et al., 1992 and unpublished records of the Queensland Turtle Research Project). These data include 11 recaptures of migrant females from the Moreton Banks of the present study.

| Rookery of origin | Present study | Reported by the public | | |
|---|---|---|---|---|
| | | trawled | | non-trawled |
| | | inside Moreton Bay | adjacent waters | |
| Mon Repos | 6 | 19 | 3 | 6 |
| Wreck Rock | 2 | 3 | 2 | 3 |
| Heron Is. | 1 | | | 1 |
| Wreck Is. | 2 | 2 | | |
| Tryon Is. | | | 1 | |
| Total | 11 | 24 | 6 | 10 |

The number of turtle barnacles, *Chelonibia testudinaria*, with diameter greater than 1cm on the carapace were counted. When the recapture interval exceeded a year, a recount of these barnacles was included in the analysis.

The gonads and associated reproductive ducts were examined using laparoscopy to assess sex, maturity and reproductive status of the turtle (Limpus & Reed, 1985). The size and morphology of the reproductive organs were used to assess sex, maturity and breeding status after methods described for *C. mydas* (Limpus & Reed, 1985), *C. caretta* (Limpus, 1985) and hawksbill turtles, *Eretmochelys imbricata* (Limpus, 1992b). Immature turtles were identified by incompletely developed gonads and associated ducts. In small immature females the oviduct was always straight and the stroma of the ovary non expanded. In small immature males the epididymis was contained within the body wall and the testis extremely ovoid in cross-section. Pubescent immature turtles were identified by the criteria of Limpus (1992b): females had a partly convoluted oviduct that was 0.3-1.5cm in diameter and oval in cross-section; males had a non-pendulous epididymis bulging from the body wall. For those turtles whose sex was not determined via laparoscopy, the sex of some males was determined using tail length (Limpus, 1985: adult male when TLC was greater than 19cm; immature male when TLC was greater than 5cm and less than 19cm). For the remainder, if TLC was less than 5cm the turtle was scored as unsexed; if CCL was less than 80cm the maturity status was scored as immature (CCL = 80cm is the size of the smallest recorded breeding adult female at the southern Great Barrier Reef [GBR] rookeries: Limpus, 1985; Limpus et al., 1984). The year of breeding for an adult female was determined as follows: breeding in the current breeding season if she was observed on a nesting beach or if she was in advanced vitellogenesis in the months preceding a breeding season; bred in the previous breeding season if she had healing corpora lutea (corpora albucantia) greater than 3mm in diameter during the months following a breeding season; bred in the penultimate breeding season if she had corpora albucantia approximately 3mm in diameter.

Some turtles were recaptured from two prior studies outside of Moreton Bay:

1. *Nesting studies*. Thousands of nesting female *C. caretta* have been tagged on nesting beaches along mainland south Queensland since 1968 and in the southern GBR since 1977 (Limpus et al., 1992). Between 1977 and 1992, comparable numbers of nesting females have been tagged annually in the two major *C. caretta* rookery regions of eastern Australia: 4304 within the Capricorn-Bunker Groups of the southern GBR; 4495 along the mainland coast from Bundaberg to Bustard Head.

2. *Hatchling marking studies*. During the period January 1976 - March 1983, 129921 hatchling *C. caretta* were marked by mutilation tagging at Mon Repos and Heron Island. These turtles can be identified to year and rookery of

FIG. 1. Subadult female *Caretta caretta* (tag number T56404) marked as a hatchling at Mon Repos and recaptured on the Moreton Banks at 15.2 years of age. See text for details.

birth by the distinctive pattern of damage to a pair of marginal scutes (one scute on either side of the posterior carapace with symmetrically placed damage within each scute. An arbitrary birth date of 1 February was assigned to these marked hatchlings within each breeding season (Limpus, 1985).

Original capture data for these turtles were obtained from the unpublished records of the Queensland Turtle Research Project.

### STUDY SITE

The principal study site was the intertidal and subtidal sand flats of the Moreton Banks (27°21'S, 153°24'E) and adjacent Maroom Banks in eastern Moreton Bay, southeastern Queensland (Limpus et al., 1994). This study also summarised the climate, tidal range, salinity, substrate and vegetation of the area.

To identify capture sites within the Moreton Banks, the banks were divided into sectors which were defined by the boundaries of the low tide drainage areas (Anon, 1987). There were two inner drainage sectors, Day's Gutter and Brown's Gutter. There were three outer drainage sectors: Boorong Bank; Fisherman's Gutter; and the western margin of the Moreton Banks from Fisherman's Gutter to Blue Pool.

## RESULTS

During the study, a total of 447 captures were made of 320 individual *C. caretta*: 434 captures of 308 turtles on the Moreton Banks and 13 captures of 12 turtles on the adjacent Maroom Banks. All except nine were released at the bank on which they were captured. Eight individuals were removed to other locations within Moreton Bay: 6 removed from Moreton Banks (two immature turtles to Peel Island [15km], two immature females to Raby Bay [20km], one adult female and one immature female to Maroom Banks [9.5km]); 1 immature female was removed from Maroom Banks and released on Moreton Banks; 1 injured immature male from the Moreton Banks was sent to Sea World for rehabilitation and subsequently released adjacent to the point of capture 30 weeks later. One immature male died during the research observations.

Most turtles were captured on the same bank on successive captures. Indeed, most were recaptured in the same drainage sector. Two turtles were recorded moving across the major channel (Rous Channel) between the Moreton and Maroom Banks. Four of the six turtles relocated

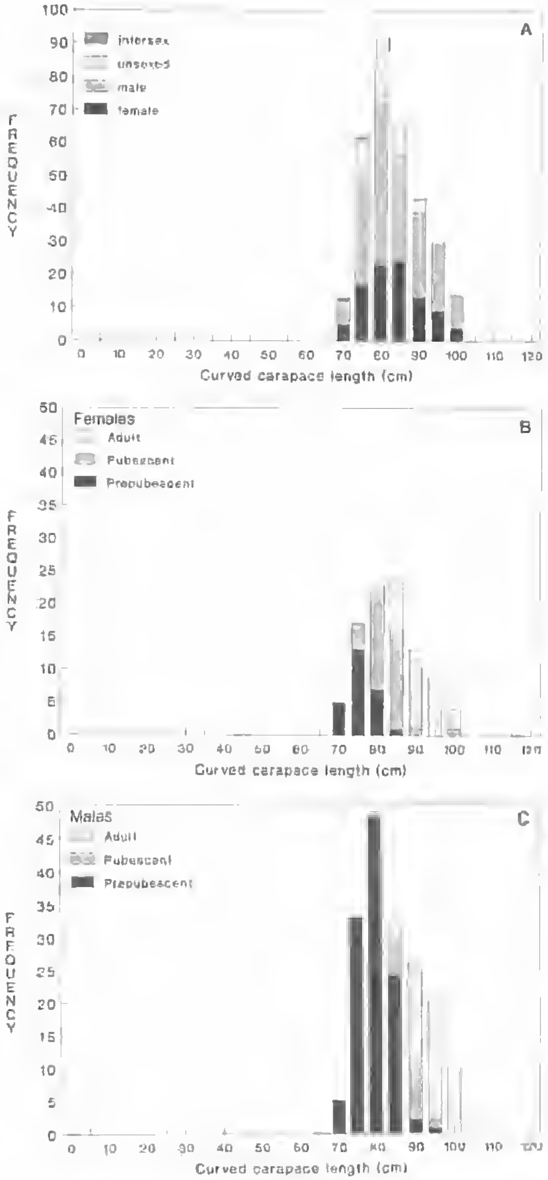


FIG. 2. Frequency distribution of size classes of *Caretta caretta* captured on the Moreton and Maroom Banks of Moreton Bay, August 1990 - June 1992. A, sex of individuals (n = 320); B, maturity status of females (n = 95); C, maturity status of males (n = 175). * denotes size of hatchling (Limpus, 1985).

to other sites from the Moreton Banks were subsequently recaptured back on the Moreton Banks: 2 from Peel Island; 1 from Raby Bay; the turtle rehabilitated at Sea World and released back at the Moreton Banks was recaptured still on the Moreton Banks 23 weeks post release. There

TABLE 2. Frequency distribution by size class, sex and maturity status for *Caretta caretta* captured on the Moreton and Maroom Banks.

| Sex | Maturity status | | | | Total |
|---|---|---|---|---|---|
| | Adult | Immature | | | |
| | | Pubescent | Pre-pubescent (CCL cm) | | |
| | | | >80.0 | <80.0 | |
| Male | 48 | 14 | 75 | 38 | 175 |
| Female | 36 | 33 | 8 | 18 | 95 |
| Intersex | | | | 2 | 2 |
| Total | 84 | 47 | 83 | 58 | 272* |

* There were an additional 48 unsexed turtles of which 13 with CCL <80.0cm were judged to be immature and 35 with CCL >80.0cm were of uncertain maturity.

were 71 instances of consecutive captures of turtles on the Moreton Banks for which the drainage sector was recorded for each capture: in 55 cases the turtle was recaptured within the same drainage sector; in 5 cases the turtle moved between adjacent outer drainage sectors; in 4 cases the turtle moved between non adjacent outer drainage sectors; and in 7 cases the turtle moved between inner and outer drainage areas. No turtle was recorded moving between adjacent inner drainage sectors. There was no significant difference in the size of turtles captured in the various drainage sectors (One way ANOV: $F = 0.87$; $df = 4,305$; $p > 0.5$).

Of the 320 turtles examined in this study, only 12 were recaptures of turtles that had been tagged elsewhere: 11 from nesting studies and 1 from hatchling marking studies. The eleven recaptures from nesting studies were of females tagged at Mon Repos and Wreck Rock on the mainland coast and Wreck and Heron Islands in the Capricorn Group, southern GBR, 402-480km to the north of Moreton Bay (Table 1). In addition, there have been 40 recaptures of tagged female *C. caretta* from elsewhere in Moreton Bay (n = 34) and adjacent waters (n = 6) that have also originated from distant nesting studies (Table 1). All of these adult female migrant recaptures were from two rookery regions, the southern GBR and the adjacent mainland near Bundaberg. The turtles had migrated from 286km up to 509km between their respective rookeries and the feeding area recapture sites. Considering only those females tagged from 1977 onwards, (the period during which nesting turtles were tagged in both rookery regions), the ratio of recaptures from each of these rookery regions (33:7) is significantly different from the ratio of the number of nesting female *C. caretta* tagged at each of these rookery regions ($\chi^2 = 15.73$, df=1, $p < 0.0001$). This suggests that a female *C. caretta* resident in Moreton Bay is more likely to nest at a mainland rookery than at a coral cay rookery of the southern GBR.

Of the eleven adult females that had been tagged while at a distant rookery prior to their having been recorded on the Moreton Banks, two have been subsequently recorded nesting in a following breeding season back at their original rookery (X22706 Wreck Rock rookery, 5yr remigration interval; T41196 Mon Repos rookery, 3yr remigration interval). Both have subsequently completed their post-nesting migrations and been recorded again on the Moreton Banks.

One immature female (T56404; captured 19 April 1992 on the Moreton Banks, CCL = 75.6cm, Fig. 1) was consistent with having been marked by mutilation tagging when it was a hatchling at the Mon Repos rookery in Jan-Feb 1977. This immature female *C. caretta* was estimated to be 15.2yr old when captured on the Moreton Banks.

No recaptures were made during this study of *C. caretta* that had been tagged at other feeding areas in Queensland (Limpus, 1985). However, outside of this study period there has been a single recapture of a *C. caretta* in Moreton Bay from another study site (tag number 5020: tagged when captured in a shark net off Billinga, Gold Coast, south east Queensland, 10 February 1971; trawled in 'Moreton Bay', 10 November 1971. Not measured, not sexed.). Except for adult females that have been subsequently recaptured

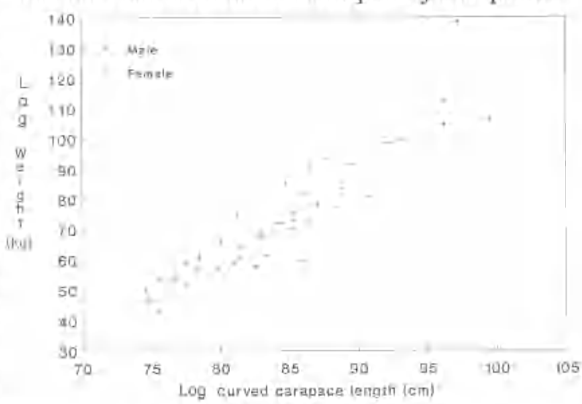


FIG. 3. Scatter plot of log carapace length (CCL) against log weight (Wt) for *Caretta caretta* captured on the Moreton Banks of Moreton Bay (n = 48).

TABLE 3. Results of stepwise unweighted logistic regression of sex ratio by size and maturity of *Caretta caretta* resident on the Moreton and Maroom Banks.

| | | | Log-likelihood ratio | | | |
|---|---|---|---|---|---|---|
| Model | Deviance | d.f. | Source | LR | d.f. | p |
| S+A+Pu+Pr+SxA+SxPu# | 12.33 | 11 | | | | |
| S+A+Pu+Pr+SxA | 12.73 | 12 | SxPu | 1.0 | 1 | 0.25>p>0.5 |
| S+A+Pu+Pr | 13.76 | 13 | SxA | 2.06 | 1 | 0.25>p>0.1 |
| A+Pu+Pr | 50.54 | 14 | S | 73.56 | 1 | p<0.001 * |
| S+A+Pu | 58.63 | 14 | Pr | 89.74 | 1 | p<0.001 * |
| S+A+Pr | 38.52 | 14 | Pu | 49.52 | 1 | p<0.001 * |
| S+Pu+Pr | 47.19 | 14 | A | 66.86 | 1 | p<0.001 * |

# SxPr dropped from model because it was too highly correlated with other variables.

S, CCL in 5 cm size increments commencing at 70 cm. A, Pu, Pr are dummy variables for adult, pubescent and prepubescent maturity status respectively; cross product variables were formed between each of the maturity classes and S. LR, log-likelihood ratio; * source makes a significant contribution to sex ratio.

on nesting beaches outside of Moreton Bay, no *C. caretta* tagged on the Moreton Banks or Maroom Banks has been reported from outside of the study site.

The size class distribution of the 320 turtles is summarised in Fig. 2. They ranged in size from immature (CCL = 70.1cm) to adult (CCL = 104.5cm) turtles. There were no turtles captured in the size range between that of hatchlings (approximate CCL = 4cm, Limpus, 1985; Limpus et al., 1984) and large immatures with CCL = 70cm. Most were large immature turtles (CCL = 70 - 90cm).

Sex and maturity was determined for 272 individuals. The population structure by sex, size and maturity is summarised (Fig. 2, Table 2). Only two of these turtles were not clearly male or female with respect to gonad development and were considered to be intersex animals. These intersex turtles are not considered in the sex ratio analysis.

Stepwise unweighted logistic regression showed that sex ratio was variable within the population, being significantly correlated to maturity status and size class of the turtles (Table 3): female proportion = $6.668M_1 + 6.913M_2 + 10.616M_3 - 0.19393*size$ (where $M_1 = 0$ for adults, $M_1 = 1$ for non adults; $M_2 = 0$ for pubescent immature turtles, $M_2 = 1$ for non pubescent immature turtles; $M_3 = 0$ for prepubescent turtles, $M_3 = 1$ for non prepubescent turtles; size denotes 5cm increments in curved carapace length beginning at 70cm; female proportion denotes the proportion of females in the subset.)

The combined *C. caretta* population inhabiting the Moreton and Maroom Banks comprised 35.2% females (95% confidence limits 5.7%, i.e. a sex ratio of 0.54:1, female to male). This pooled sex ratio is significantly different from 1:1 ($\chi^2 = 23.7$, df = 1, p<0.001).

The mean size of these turtles by maturity status is summarised (Table 4). Of the 95 females examined for sex and maturity, there were 38% adult, 35% pubescent immature and 27% prepubescent immature turtles. The mean size (CCL) of adult females was 92.5cm, of pubescent females was 84.9cm and of prepubescent females was 78.4cm. Of the 175 males similarly examined, there were 27% adult, 8% pubescent immature and 65% prepubescent immature turtles. The mean size (CCL) of adult males was 96.1cm, of pubescent males was 90.6cm and of prepubescent males was 81.9cm.

There was no distinct carapace size class that separated adults from immature turtles for either sex (Fig. 2). For both sexes there were immature turtles larger than the mean size of the adults (Table 4). The adult males were significantly larger than the adult females ($t_{1,82} = 11.72$, $p < 0.001$).

Forty-eight turtles were weighed (Fig. 3). Because the log/log regression equations of CCL against weight by sex were coincident, the data was pooled for all turtles. This gave a significant correlation between size and weight of the turtles :$\log(WT) = 3.1655\log(CCL) - 4.2416$ ($r^2 = 0.889$; F = 368.4 df = 1,46).

While there were significant differences in tail length of adult males and females, there was considerable overlap in the tail lengths of immature male and female turtles and some adult female turtles (Fig. 4). In this sample, all turtles sexed by gonad examination that had TLC > 1.0cm were males and all turtles with CCL > 88cm and TLC < 1.0cm were female. Based on this sample, *C. caretta* with CCL 88cm and TLC 1.0cm could not be reliably sexed using external measurements.

The frequency distribution by breeding status of adult females is summarised by year in Table 5. No

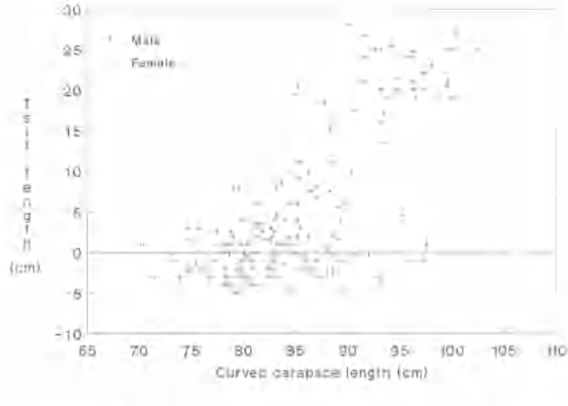


FIG. 4. Scatter plot of carapace length (CCL) against tail length from the carapace (TLC) for *Caretta caretta* captured on the Moreton and Maroom Banks of Moreton Bay.

adult female examined in the present study showed evidence of breeding in two consecutive breeding seasons. The results as presented in Table 5 have included young adults that have not yet recruited to the breeding population but whose reproductive system is structurally indistinguishable from that of adults that have bred successfully in the past, except for the absence of corpora albucantia. There was no significant difference in the proportion of adult female *C. caretta* that bred from this feeding area in the three breeding seasons 1989 - 1992 ($\chi^2 = 2.224$, df = 2, p = 0.33). The mean proportion of the adult females that bred in any one year was 0.20 (95% confidence limits = 0.09).

A total of 55 turtles showed evidence of anthropogenic injuries and/or health problems. Twenty turtles (6.3%) appeared to be in poor health as evidenced by their leanness and plastron concavity (mean CCL = 79.7cm, SD = 4.73, range = 70.3-88.1, n = 19). One turtle (0.3%) had curvature of the spine (scoliosis: prepubescent male, CCL = 88.9cm). Injuries resulting from anthropogenic causes were recorded for 6.9% of the turtles: 17 (5.3%) with healed or healing propeller cuts to the carapace (9 adult, 1 pubescent, 6 prepubescent turtles; mean CCL = 90.6cm, SD = 8.06, range = 75.6-102.3, n = 17) and 5 (1.6%) with healed or healing carapace fractures consistent with having been hit by a boat or having been dropped on the sorting tray of a trawler (all prepubescent turtles, mean CCL = 81.5cm, SD = 2.01, range = 79.3-85.0, n = 5). The closeness and length of cuts on the turtles recorded with propeller damage were consistent with damage that could be inflicted by small outboard motors. Fibropapillomas were present on 14 turtles (4.4%; 8 adult, 4 pubescent, 2 prepubescent; mean CCL = 90.9cm, SD = 5.60, range = 80.3-99.2, n = 14). If fibropapillomas are a consequence of pollution (Balazs & Pooley, 1991), then 10.7% of the turtles displayed evidence of anthropogenic impacts.

The majority of these turtles carried substantial numbers of epifauna and epiflora on their carapaces and to a lesser extent on the flippers, head and plastron. The Turtle Barnacle (*Chelonibia testudinaria*) and an oyster (*Ostrea* sp.) were the most obvious common commensal faunal species on the carapace of these turtles. The mean number of large *C. testudinaria* (barnacles larger than 1cm in diameter) per carapace was 6.8 (SD = 14.0, range = 0 - 94, n = 296). The other barnacles included *Stomatolepas praegustator* (in the buccal cavity and skin folds at the base of the neck and groin), *Platylepas decorata* (mostly on the skin of neck and flippers), *Tubicinella cheloniae* (burrowed into the dorsal carapace and ventral surface of the posterior marginals) and *Balanus trigonus* (on the carapace). Other species of oyster regularly found attached to the dorsal surface of the carapace included *Pinctada margaritifera* and *Saccostrea cucullata*. Other commensal fauna included worms (polychaetes and parasitic leeches, *Ozobranchus margoi*), Cunjevoi (*Pyura stolonifera*) and other smaller ascidians, amphipods and crabs. The gastropod *Thalotia marginata* was occasionally found grazing on the algal turf growing on the carapace. Conspicuous algae growing on the carapace included *Enteromorpha intestinalis*, *Ulva* sp. and *Gracilaria edulis*. Schools of small Golden Trevally (*Gnathanodon speciosus*) often were seen swimming immediately in front of the snout of swimming turtles and feeding around foraging turtles.

Six turtles were captured which lacked the epifauna and epiflora that characterise the *C. caretta* resident in this study site. These turtles appeared to be 'clean' and more striking in their colouration; all had intensely black tomia within the buccal cavities; all were small turtles (mean CCL = 79.8cm, SD = 2.71, range = 74.9-83.0, n = 6); all were prepubescent immature; 4 males, 2 unsexed. These turtles are interpreted as having recently recruited to residency in the feeding area and had not as yet acquired the local epizoon and epiphytic organisms. One of these new recruits was the only turtle recorded during the study that had open but healing wounds from a recent mauling from a shark.

TABLE 4. Size of *Caretta caretta* from eastern Moreton Bay by sex and maturity status.

| | Maturity | Curved carapace length (cm) | | | |
|---|---|---|---|---|---|
| | | mean | s.d | range | n |
| Female | adult | 92.51 | 5.263 | 82.2-103.5 | 36 |
| | pubescent | 84.89 | 4.542 | 79.0-102.8 | 33 |
| | prepubescent | 78.43 | 3.728 | 70.1-85.7 | 26 |
| Male | adult | 96.12 | 4.388 | 85.1-104.5 | 48 |
| | pubescent | 90.55 | 4.058 | 84.8-96.5 | 14 |
| | prepubescent | 81.87 | 4.202 | 70.3-95.2 | 113 |

Many of the turtles were observed digging shallow broad depressions in the substrate with a sweeping action by the front flippers, thus creating a low vertical wall in front of the turtle. Given that the stomach contents of stranded turtles in adjacent areas include large quantities of a number of species of bivalve molluscs that burrow into the substrate (Razor Clam, *Pinna bicolor*; Mud Ark, *Anadara trapezia*; Chinese Fingernail Shell, *Solen grandis*: unpubl. data), it is presumed that the *C. caretta* observed digging these depressions were actively foraging. Recently worked feeding depressions are a common sight over the Moreton Banks. Similar feeding behaviour was observed with *C. caretta* at this study site in 1989 (T. Preen, pers. comm.). Not all feeding involved digging for prey items: an adult male, CCL = 94.2cm, was seen feeding on the anemone *Stichodactyla haddoni* while a large immature turtle was captured with a Blue Swimmer Sand Crab (*Portunus pelagicus*) in its mouth. As was observed with *C. mydas* feeding over the same banks, the foraging *C. caretta* tended to move in across the intertidal flats with the rising tide and fall back to deep water with the ebbing tide.

## DISCUSSION

Old confirmed records of *C. caretta* from Moreton Bay have been difficult to locate. The oldest specimen record is a Queensland Museum specimen from the Bay that was registered in 18 August 1964 (QMJ13183: from Sandgate, dentary only, originally registered as *Eretmochelys imbricata*). Backhouse (1843) talks of three species of turtles in Moreton Bay but does not identify which ones. There had been a *C. mydas* fishery in Moreton Bay spanning at least 50 years from the 1890s (Limpus et al., 1994). However, until the 1960s there appears to be no published recognition of *C. caretta* in Moreton Bay. This reflects that the species was perceived as insignificant compared to *C. mydas* which had economic and nutritional values. In contrast with *C. mydas* populations in Queensland (Limpus et al., 1994), there is no indication that *C. caretta* in Moreton Bay or elsewhere in Queensland were subjected to intense harvest in the past.

The Moreton Bay area is the southern limit for annual successful nesting for the species. Further south, nesting is not an annual event although nesting by *C. caretta* has been confirmed from as far south as Ballina, NSW (unconfirmed records from as far south as Newcastle, 33°S) while the large nesting populations occur to the north of Moreton Bay (Limpus, 1985). Bowen et al. (1994) have identified this eastern Australian breeding assemblage as the only significant *C. caretta* breeding population for the South Pacific Ocean. Further, they demonstrate that the eastern Australian population is genetically distinct from the population breeding in the North Pacific. While small numbers of *C. caretta* (probably 1-3 individuals) nest each year on the seaward beaches of North Stradbroke and Moreton Islands (Limpus, 1985; Limpus & Couper, unpubl. data), none of these nesting turtles have been tagged. It is thus not possible at present to determine if any of the local nesting is by adult females that live year round in Moreton Bay or whether they are turtles undertaking breeding migrations from more distant feeding areas. Given the low level of local nesting, we conclude that the majority of

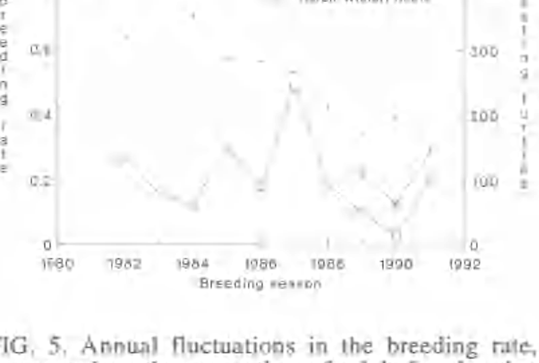


FIG. 5. Annual fluctuations in the breeding rate, measured as the proportion of adult females that prepared for breeding for the year, of *Caretta caretta* resident in two feeding grounds in eastern Australia (Heron-Wistari Reefs: Limpus & Reimer, 1994. Moreton Bay: present study). These fluctuations are compared with the fluctuations in the number of *Caretta caretta* that have bred annually at the Mon Repos and adjacent rookeries of the Woongarra coast (Limpus & Reimer, 1994).

TABLE 5. Frequency distribution by breeding status and breeding season for adult female *Caretta caretta* recorded from Moreton Bay during the study period. Adult females were identified by gonad examination following Limpus (1985,1992b) or by having been recorded laying eggs at a distant rookery during the current breeding season.

| Breeding season | Adult | | | | Total |
|---|---|---|---|---|---|
| | Breeding[1] | Non-breeding2 | Pre-breeding | | |
| | | | Vitellogenic[3] | Non-vitellogenic[4] | |
| 1989/90 | 5 | 17 | 0 | 1 | 23 |
| 1990/91 | 4 | 21 | 1 | 5 | 31 |
| 1991/92 | 7 | 10 | 2 | 5 | 24 |

[1] adults that bred (ovulated) in the current breeding season.
[2]adults that have ovulated in previous breeding seasons as indicated by the presence of corpora albucantia 3 mm and which did not breed in the current breeding season.
[3]adults that have yet to breed (no corpora albucantia) and the vitellogenesis for the current season did not result in ovulation.
[4]adults that have yet to breed (no corpora albucantia) and were non-vitellogenic for the season.

*C. caretta* that live in Moreton Bay migrate elsewhere to breed. Based on tag recoveries (Table 1), the present study indicates that most of the resident turtles can be expected to migrate to breed on mainland beaches of the Bundaberg coast, with only a small proportion of the Moreton Bay residents migrating to nest on the islands of the southern GBR. Moreton Bay is a significant feeding ground for the eastern Australian nesting *C. caretta*.

The high incidence of recaptures of individual turtles within a localised feeding area and the absence of recaptures elsewhere, except for breeding migrations (present study; Limpus, 1985, 1989, 1991; Limpus & Reimer, 1992; Limpus et al. 1992), indicate that there is little or no substantial movement of *C. caretta* between widely separated feeding areas. The limited number of recaptures available (tag numbers X28101, T22706, T41196) show that Moreton Bay resident females have a high fidelity to this feeding area to which they return following a breeding migration (Limpus, 1989; Limpus et al., 1992; present study).

As for the resident feeding population on the coral reefs of the southern GBR, the *C. caretta* population living on the Moreton Banks is comprised only of large immature and adult turtles (Limpus, 1985). The smallest turtle captured in the present study was 70.1cm and the smallest beachwashed specimen reported from the Moreton Bay area during the period of the present study had a CCL = 62.5cm (QM J55131). Post hatchling *C. caretta* (i.e. CCL = 4-30cm) are rarely encountered in eastern and northern Australia except on the ocean beaches adjacent to Moreton Bay and in northern NSW when strong onshore winds strand small *C. caretta* post hatchlings (CCL = 4-10cm) during March - May (Limpus, Walker & West, 1994; Limpus & Couper, unpubl. data). It is presumed that these young *C. caretta* were travelling south in the East Australian current from the major rookeries of south Queensland (Walker, 1994). The authors know of only a few isolated records of small immature *C. caretta* (CCL = 30-70cm) in Australian waters (Limpus, Walker and West, 1994). The present study indicates that immature *C. caretta* recruit to reside in the Moreton Banks feeding ground at a mean CCL = 79.8cm. The total absence of coastal epifauna and epiflora on the turtles identified as new recruits suggests that this size range of *C. caretta* is recruiting from open ocean habitat(s).

Once young turtles recruit to the Moreton Banks, they remain as residents and all size classes occur from the small immatures (CCL = ~70 cm) up to large adults of both sexes. These *C. caretta* occur on the Moreton Banks all year round and within the shallow subtidal and intertidal feeding areas these *C. caretta* are primarily carnivorous. The resident population is strongly biased to males (64.8%) and to immature size classes (62% of females, 73% of males). The resident *C. caretta* of the coral reefs of the southern GBR are also significantly biased to males (Limpus, 1985). This contrasts with the strong bias to females (66%) recorded for the *C. mydas* resident on the Moreton Banks (Limpus et al., 1994). Sexual maturity for both sexes does not usually occur at the minimum breeding size but at some larger size. The adult females recorded from the Moreton Banks were not significantly different in size from those resident on the coral reefs adjacent to Heron Island in the southern GBR (Limpus, 1985. One way ANOV: $F = 2.2$; $df = 1,55$; $0.5 > p > 0.2$), the only other site in eastern Australia where foraging adult *C. caretta* have been measured. In contrast the adult females foraging on the Moreton Banks are significantly smaller than the nesting females on the Bundaberg coast (Limpus, 1985. One way ANOV: F

= 19.0; df = 1,2241; p > 0.5). This suggests that there are other feeding grounds that supply the larger sized nesting females to the Bundaberg coast. The adult males resident on the Moreton Banks were not significantly different in CCL when compared to the small sample of adult males captured at courtship in the southern GBR (Limpus, 1985. One way ANOV: F = 0.095; df = 1,53; p > 0.5).

The proportion of adult females that prepared for breeding from the Moreton Bay feeding area was consistently higher in each year, 1989-1991, than the proportion that prepared to breed from the Heron-Wistari Reefs feeding area of the southern GBR in the same years (Fig. 5). The proportion of females that prepared to breed each year from the Moreton Bay feeding area did not parallel the decline in nesting females recorded at Mon Repos and adjacent rookeries on the Woongarra coast (Fig. 5) and at other eastern Australian rookeries (Limpus & Reimer, 1994). This adds further weight to the argument that the eastern Australian decline in *C. caretta* nesting numbers is not the result of annual fluctuations in the proportion of turtles migrating from the feeding areas but is an index of the overall reduction in the total population within the southwestern Pacific Ocean foraging range for the species (Limpus & Reimer, 1994).

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